PHYTOTOXICOLOGY

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MERCURY RESULTS:

ICI, CORNWALL

(1995)

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Phytotoxicology Vegetation and Soil Mercury Results: ICI, Cornwall (1995)

Introduction

Phytotoxicology surveys have been conducted regularly since 1976 to assess the degree and extent of mercury contamination of vegetation and/or soil in the vicinity of ICI Forest Products Inc. in Cornwall. The ICI chlor-alkali plant, the primary mercury source, was closed in March 1995, but decommissioning activities of the mercury cell rooms resulted in continuing emissions of mercury during the summer. This was revealed by the MOEE TAGA air monitoring survey in July 1995 and by ICI's own cell room monitoring data. Because of this, the Phytotoxicology tree foliage survey was repeated in August, and vegetables were collected from gardens immediately east of ICI in September. Soil also was sampled from a few residential lawns and gardens in May and September, respectively. These surveys were requested by the MOEE's Eastern Region Cornwall District office.

Sample Collections

Soil Profile Sampling

On May 18 1995, three residential properties immediately east of ICI were sampled as reference sites for determining the depth of mercury contamination in the soil profile and for monitoring the expected decline in mercury over time. Soil at three depths (0-5, 10-15 and 25-30 cm) was collected from two separate back lawns on Gulf St. (Sites A and B) and from a lawn (Site C) on Brookdale Avenue (see Figure 1). Triplicate soil samples at each depth were collected with an Oakfield soil corer. Each sample consisted of about 20 random cores. The surface soil samples at all sites consisted of either loam or clay-loam and the sub-soil (25-30 cm) was predominately clay. These same sites will be re-sampled every three to five years to monitor the expected decline in mercury in the soil over time subsequent to the closure of the ICI mercury cell chlor-alkali facility.

Tree Foliage

On August 23 and 24 1995, foliage was sampled from 22 maple trees situated throughout the City of Cornwall at increasing distances downwind (east) and upwind (west) of ICI. Control sites in Ingleside, approximately 20 km west of ICI, also were sampled. The same maple trees were sampled in 1994. At all sites, duplicate foliage samples were collected from middle branches exposed to ICI, using standard MOEE procedures.

Garden Sampling

On September 18 1995, vegetables were collected from five gardens (numbered 1 to 5 in Figure 1) to the east of ICI. This sampling was conducted to determine the mercury levels that area residents were exposed to through eating selected home-grown vegetables. Beet tops were collected from gardens 1 and 5, leaf lettuce from gardens 2 and 3, and beans from gardens 3 and 4. Sweet corn ears also were sampled from garden 4. Garden 4 was the large community garden that was established in 1995 by the Mayor's Task Force on Healthy Lifestyles. It was located in the open field just behind the residences on the north side of Fifth Street. Control samples of beet tops, leaf lettuce, bean and corn were also collected from control gardens remote from ICI. The vegetable samples from all sites were potentially consumable, with the exception of the mature lettuce leaves from garden 3 and the control site. These lettuce plants had bolted and gone to seed.

On September 18, soil (0-15 cm depth) was sampled from two gardens (3, 4) not previously tested for mercury. Two soil samples from garden 3, and five samples from the large community garden (4), were collected. The community garden, which was about 40 m long by 15 m wide, was divided into 4 sections and a single soil sample was collected from each section with a hand shovel. From the first section (west end), where the bean and corn samples were collected, separate soil samples were collected from around the bean and corn plants. Duplicate soil samples (0-5 cm) from the undisturbed grassy field immediately west of the community garden were also collected.

Sample Submission

All samples were returned to the Phytotoxicology processing laboratory. Here, the samples were dried and ground (vegetation) or sieved (soil) and then stored in glass jars. Prior to drying, the samples of beet tops, lettuce and beans were washed as they would be prior to consumption, and the edible corn kernels were removed from the corn cobs. All vegetable samples were then weighed on a fresh and dry weight basis, so the (dry weight) analytical data could be converted back to fresh "as consumed" values. All vegetation and soil samples were then submitted to the MOEE's Laboratory Services Branch at Resources Rd. for mercury analysis.

Analytical Results

All results are reported as µg/g (micrograms per gram, commonly referred to as ppm or parts per million). The results were compared with the control data and/or with the Phytotoxicology Section Upper Limit of Normal (ULN) urban guidelines (see Appendix A). ULNs reflect the expected upper limit of normal concentrations in urban areas not influenced by point sources of emissions. A level in excess of the ULN indicates the likely presence of a source of contamination.

Soil Profile Results

Mercury concentrations decreased with depth in the soil profile at Sites A, B and C (see Table 1). The highest mean mercury levels were detected in the surface soil at Sites A (1.97 µg/g) and B (1.67 µg/g), with these results being about 4 times the corresponding mean concentrations at depth (25-30 cm). At all sites, the mean soil mercury concentration at the 0-5 and 10-15 cm depths exceeded the ULN (0.5 µg/g), especially the surface soil at Sites A and B. The depth samples from all sites had a mean mercury concentration below the ULN, even though a few replicates from Sites A and B were slightly above the ULN. This data suggests that the soil mercury contamination in the residential area immediately east of ICI is largely confined to the upper 30 cm depth. This is consistent with historical atmospheric deposition and with the results from other Phytotoxicology studies of heavy metal soil contamination.

Tree Foliage Results

Table 2 summarizes the mercury results for the maple foliage sites within 500 meters, between 500 and 1000 meters, and at greater than 1000 meters from ICI from 1987 to 1995. The underlined data exceed the ULN mercury guideline for tree foliage (0.3 µg/g).

The August tree foliage data further confirms that ICI was a mercury source during the 1995 growing season, even though the chlor-alkali plant closed in March. This implicates the mercury cell room dismantling as the primary source. Site 4, in the residential area just east of ICI, had the highest foliar mercury level (1.5 µg/g), which was 5 times the ULN (0.3 µg/g).

Nevertheless, foliar mercury levels overall were considerably reduced in 1995 relative to previous surveys. The mercury level at Site 4 (1.5 µg/g) was reduced by about 60% compared to 1993 (3.95 µg/g) and 1994 (3.85 µg/g). The mean concentration for the five closest sites (0.75 µg/g) was reduced by about 54% compared to 1994 (1.62 µg/g) and 83% compared to 1993 (4.46 µg/g). The means shown for the sites between 500 and 1000 m and at greater than 1000 m also were markedly reduced from those of previous surveys. Over the eight year period from 1987 to 1995, the mean mercury concentration of all common 22 Cornwall tree foliage sites has varied from a high of 1.29 µg/g in 1993 to a low of 0.23 µg/g in 1995.

Most Cornwall foliage sites in 1995 had a mercury level greater than the control data, but the ULN was exceeded only at Sites 2, 4, 6 and 14 within 500 m to the east of ICI. In contrast with previous surveys, in 1995 the ULN was not exceeded at any of the sites beyond 500 m. The 1995 foliar results are compared to the 1994 data in Figures 2 and 3. These contour maps were derived using the Surfer computer software program. The mercury contamination contours in these figures are estimates, the actual concentrations are known only at the sample sites. These contour maps illustrate the reduction in the degree and extent of the foliar mercury contamination in 1995.

Garden Results

The September vegetable results are presented on both a dry and a fresh weight basis in Table 3. The beet tops from garden 1, and the lettuce from gardens 2 and 3, had mercury concentrations well above control levels. The highest level, which was detected in the beets tops (0.66 µg/g, dry wt.) at garden 1, was about 66 times higher than the control level. The highest leaf lettuce concentration (0.20 µg/g, dry wt.) was about 20 times the control level (<0.01 µg/g). Mercury concentrations in the bean and corn samples from gardens east of ICI were comparable to the control data. ULNs for vegetable crops have not been established.

In the 1993 garden study, two plots with beets and leaf lettuce were situated in the area of gardens 1 and 2. These plots in mid-August 1993 had mercury levels (dry wt.) of 0.84 µg/g in beet tops and 0.67-0.84 µg/g in lettuce leaves. Compared to these and other produce sampled from the same residential community in 1993 (0.89 µg/g in beet tops; 1.3 µg/g in lettuce), the beet top and lettuce samples in 1995 had generally lower mercury concentrations in spite of the longer exposure period.

The two soil samples from garden 3 had mercury levels of 0.56 and 0.40 µg/g, with the mean (0.48 µg/g) being just under the ULN (0.5 µg/g). Soil samples from the community garden (4) had mercury levels ranging from 1.5 to 2.1 µg/g (mean 1.8 µg/g). These results, and the soil from the adjacent field (mean 1.6 µg/g), exceeded the ULN. All of the 1995 soil results fall within the range in garden soil concentrations (0.07-2.4 µg/g) that were detected in the community east of ICI in 1993. The MOEE health risk study conducted in 1993/94 concluded that these soil mercury levels do not pose a health risk. Phytotoxicology studies illustrated conclusively that root uptake of mercury from soil is minimal, and that the air is the primary pathway by which mercury enters the plant.

MOEE health risk assessment scientists with the Standards Development Branch reviewed the 1995 vegetable data and re-affirmed that the 1995 garden produce did not pose a risk to human health. In the fall (1995), letters were delivered by Cornwall MOEE staff to the area residents informing them that their garden vegetables remained safe to eat, and that additional monitoring would be conducted by the MOEE in 1996.

MOEE TAGA Air Survey and ICI Emissions Data

Air monitoring in 1995 was conducted by the MOEE's Specialized Monitoring Section (TAGA Group) in the area of ICI from July 17 to 28. The survey revealed that ambient mercury levels were similar to those measured during the previous TAGA air survey in 1993.

ICI's cell room monitoring data (1995) also indicated that the decommissioning activities that followed the chlor-alkali plant closure in March resulted in mercury emissions to the atmosphere. ICI cell room emissions of mercury from May to August 1995 averaged 51% of the previous three years, when the chlor-alkali plant was operating. The 1995 August emissions were equivalent to 75% of the average August emissions from 1992 to 1994.

Conclusion

The 1995 vegetation data, together with the TAGA (MOEE) and ICI monitoring data, revealed that ICI continued to be a mercury source during the growing season, despite the closure of the chlor-alkali plant in March. This implicates emissions from the mercury cell room dismantling as the source of the elevated mercury levels in the tree foliage and leafy vegetables collected in 1995. The degree and extent of mercury contamination of tree foliage was reduced in 1995, with the mean mercury concentration of all common Cornwall sites being the lowest since the survey began in 1976. Foliage sites exceeding the ULN were confined to within 500 m east of ICI. In most previous years, the ULN was exceeded at sites up to about 1 km east of ICI. MOEE health risk assessment scientists reviewed the 1995 vegetable data and concluded that there was no health threat in consuming vegetables from gardens in the vicinity of ICI.

Table 1: Soil Profile Mercury Concentrations*: ICI, Cornwall - May 1995.				
Sampling Location	**Rep, Mean & SD****	**Sampling Depth (centimeters)**		
		Soil 0-5	**Soil 10-15**	**Soil 25-30**
Site A (Gulf Ave.)	Rep 1	1.80	1.40	0.52
	Rep 2	1.90	1.30	0.53
	Rep 3	2.20	1.20	0.37
	Mean (SD)	**1.97 (0.21)**	**1.30 (0.10)**	**0.47 (0.09)**
Site B (Gulf Ave.)	Rep 1	1.60	0.80	0.40
	Rep 2	1.70	1.00	0.27
	Rep 3	1.70	1.20	0.58
	Mean (SD)	**1.67 (0.06)**	**1.00 (0.20)**	**0.42 (0.16)**
Site C (Brookdale Ave.)	Rep 1	1.40	0.52	0.15
	Rep 2	1.50	0.48	0.14
	Rep 3	1.30	0.64	0.13
	Mean (SD)	**1.40 (0.10)**	**0.55 (0.08)**	**0.14 (0.01)**

*µg/g, dry weight. ** SD = Standard deviation
Shaded results exceed Phytotoxicology Section urban ULN guideline (0.5 µg/g), see Appendix A.

Table 2: Tree Foliage Mercury Concentrations: ICI, Cornwall - August 1987-1995.

Site No.	Distance (m) & Direction from ICI Hg Cell Room	Maple Species	Foliar Mercury Concentration*							
			1987	1989	1990	1991	1992	1993	1994	1995
Sites Between 0 and 500 m of ICI										
1	360 N	Silver	1.80	0.26	0.27	0.24	0.50	12.3	0.25	0.13
2	360 NNE	Manitoba	10.30	0.85	0.92	1.90	0.69	2.90	0.86	0.52
4	240 E	Manitoba	8.60	3.80	8.75	2.60	1.30	3.95	3.85	1.5
6	400 ENE	Sugar	3.00	2.50	4.25	2.90	2.30	2.80	2.75	0.89
14	240 SW	Norway	0.96	0.38	0.73	1.10	0.38	0.33	0.39	0.71
	Mean		**4.93**	**1.56**	**2.98**	**1.75**	**1.03**	**4.46**	**1.62**	**0.75**
Sites Between 500 and 1000 m										
8	560 E	Red	0.75	0.37	0.17	0.59	0.41	0.71	0.30	0.14
9	600 ENE	Silver	1.65	0.65	0.62	0.89	0.79	1.10	0.90	0.27
10	750 NNE	Silver	0.45	0.18	0.01	0.21	0.22	0.74	0.22	0.06
12	680 NW	Silver	0.20	0.02	0.08	0.04	0.05	0.08	0.03 T	0.01 T
16	760 ESE	Silver	0.27	0.15	0.03	0.23	0.10	0.36	0.10	0.05 T
19	760 SW	Norway	0.86	0.18	0.22	0.25	0.17	0.63	0.10	0.12
21	720 SSE	Silver	0.44	0.31	0.13	0.31	0.12	0.53	0.08	0.04 T
23	760 N	Silver	0.10	0.04	0.04	0.04	0.04	0.08	0.01 W	0.02 T
27	840 E	Silver	0.41	0.22	0.06	0.35	0.34	0.47	0.20	0.11
33	700 W	Norway	0.27	0.11	0.09	0.04	0.04	0.11	0.03 T	0.05 T
	Mean		**0.54**	**0.22**	**0.15**	**0.30**	**0.23**	**0.48**	**0.19**	**0.09**
Sites Greater than 1000 m										
11	1120 NE	Silver	1.15	0.35	0.01	0.46	0.41	0.27	0.32	0.13
22	1700 E	Silver	0.10	0.13	0.07	0.09	0.10	0.15	0.05 T	0.04 T
25	1440 NNE	Manitoba	0.21	0.14	0.09	0.05	0.05	0.17	0.07	0.05 T
32	1880 ENE	Silver	0.29	0.15	0.09	0.12	0.09	0.16	0.07	0.05
35	1740 WSW	Silver	0.20	0.03	0.05	0.03	0.05	0.17	0.01 W	0.02 T
36	2300 NE	Manitoba	0.48	0.09	0.13	0.14	0.10	0.18	0.08	0.05
37	3500 NE	Norway	0.19	0.10	0.08	0.04	0.07	0.11	0.04 T	0.04 T
	Mean		**0.37**	**0.14**	**0.07**	**0.13**	**0.12**	**0.17**	**0.09**	**0.05**
Overall Mean (22 Sites)			**1.49**	**0.50**	**0.77**	**0.57**	**0.38**	**1.29**	**0.49**	**0.23**
Controls (>20 km)		Manitoba	0.04	0.06	0.03	0.03	0.04	0.10	0.01 W	0.01 W
		Silver	0.03	0.05	0.03	0.02	0.03	0.08	0.01 W	0.02 T
		Norway	NR	0.04	0.04	0.02	0.03	0.06	0.01 W	0.01 T

* ug/g dry weight, mean of duplicate samples and analysis.
W - Actual concentration is less than 0.01 ug/g. This value was halved (= 0.005 ug/g) in calculating the overall mean for each specified area in 1994.and 1995. T - A measurable trace amount, interpret with caution.
Note: Values underlined exceed urban ULN guideline (0.3 ug/g), see Appendix A

Table 3: Vegetable Mercury Concentrations: ICI, Cornwall - September 1995

Gardens Sampled	Vegetable Sample	Concentration*	
		Dry Weight	Fresh Weight (as consumed)
Garden 1 (Brookdale Ave.)	*Beet Tops*	0.66	0.059
Garden 2 (Brookdale Ave.)	*Leaf lettuce*[a]	0.09	0.007
	Leaf lettuce[a]	0.20	0.016
Garden 3 (Fifth St.)	*Leaf Lettuce*	0.17	0.014
	Yellow Bean	<0.01	<0.001
Garden 4 (Community Garden - Fifth St.)	*Green Bean*	<0.01	<0.001
	Sweet Corn	<0.01	<0.003
Garden 5 (Munro Ave.)	*Beet Tops*	0.12 (0.18)***	0.011 (0.016)
Distant Gardens (Controls)	*Beet Tops*	<0.01	<0.001
	Leaf lettuce	<0.01	<0.001
	Green Bean	<0.01	<0.001
	Yellow Bean	<0.01	<0.001
	Sweet Corn	<0.01	<0.003
1993 Garden Study Sites Close to ICI	*Beet Tops*	range: 0.10 - 0.89 mean: 0.58	0.008 - 0.07 0.05
	*Leaf lettuce***	range: 0.03 - 1.3 mean: 0.66 & 0.53	0.001 - 0.026 0.013 & 0.02

*µg/g, mean of duplicate samples and analysis, with the exception of the Garden 1 property. Here, there were two separate small gardens and a single lettuce sample was collected from each, as denoted by the superscript [a].

** Based on two collections: July and August.

*** Maximum concentration is shown in brackets, as there was a big difference in concentrations between the two reps.

Figure 1: Soil Profile Sites (A, B, C) and Gardens (1-5) Sampled East of ICI - 1995

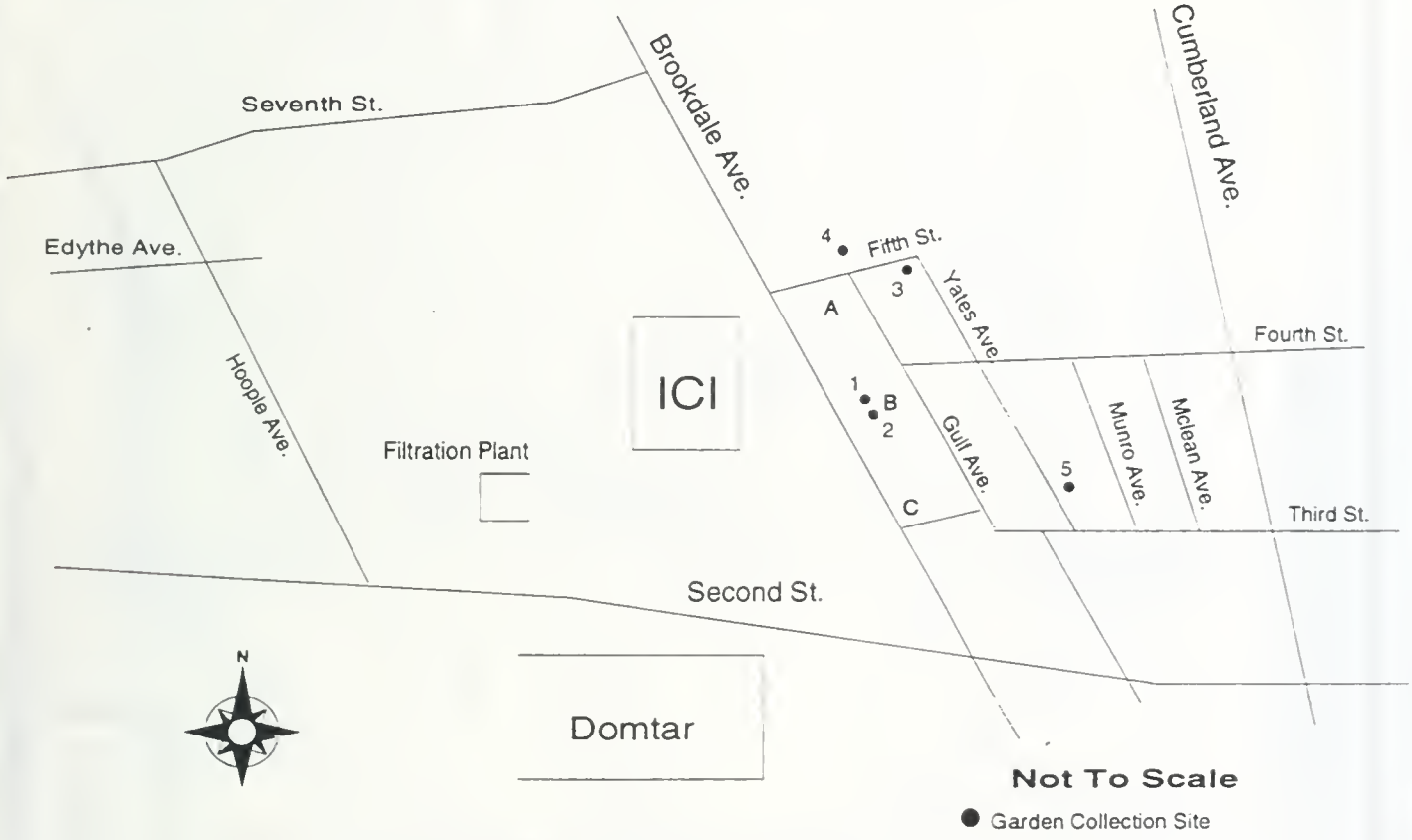

Figure 2: Foliage Sites in Relation to ICI, Cornwall (1995).

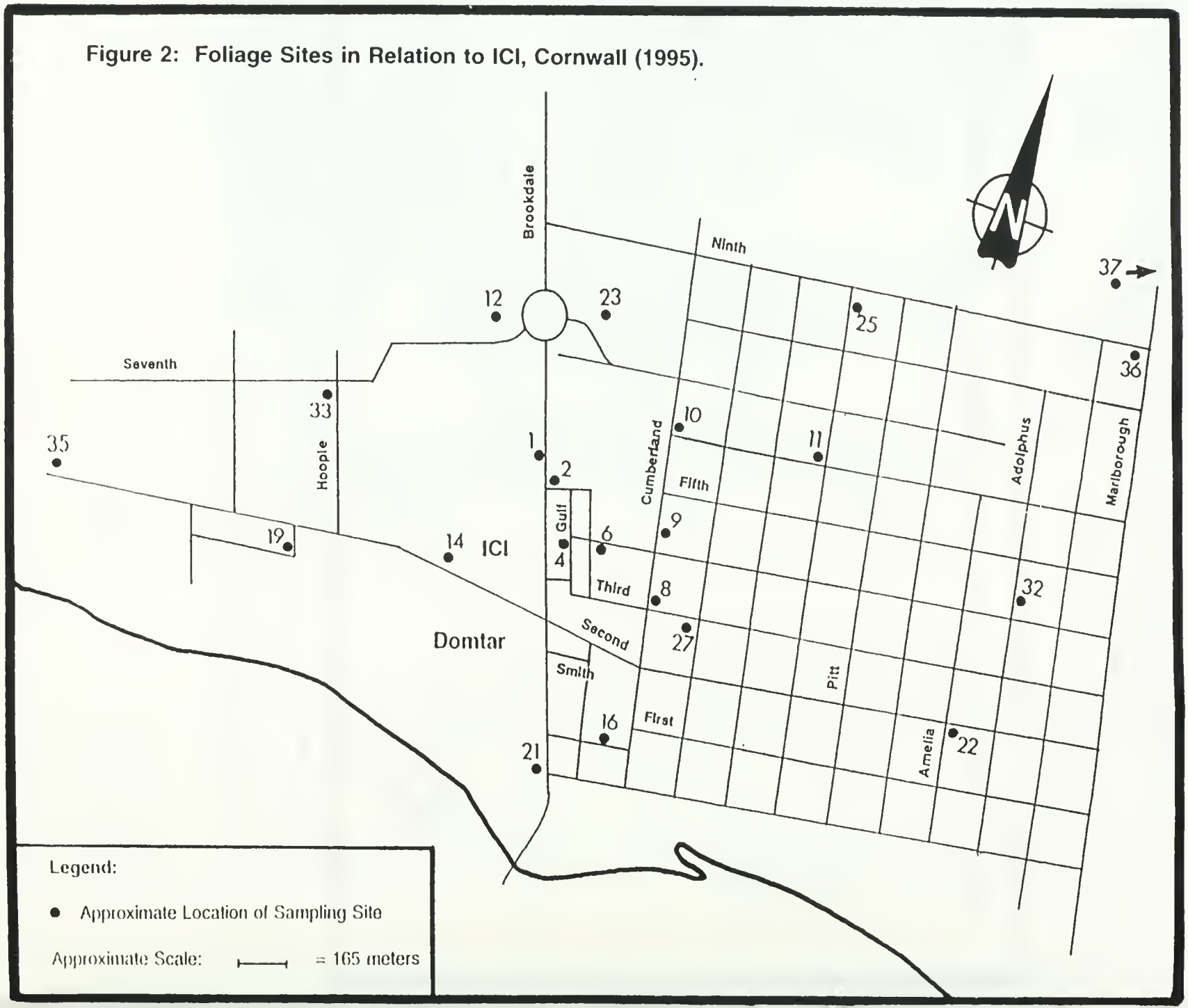

Figure 3: Mercury in Tree Foliage: Cornwall - August 1995

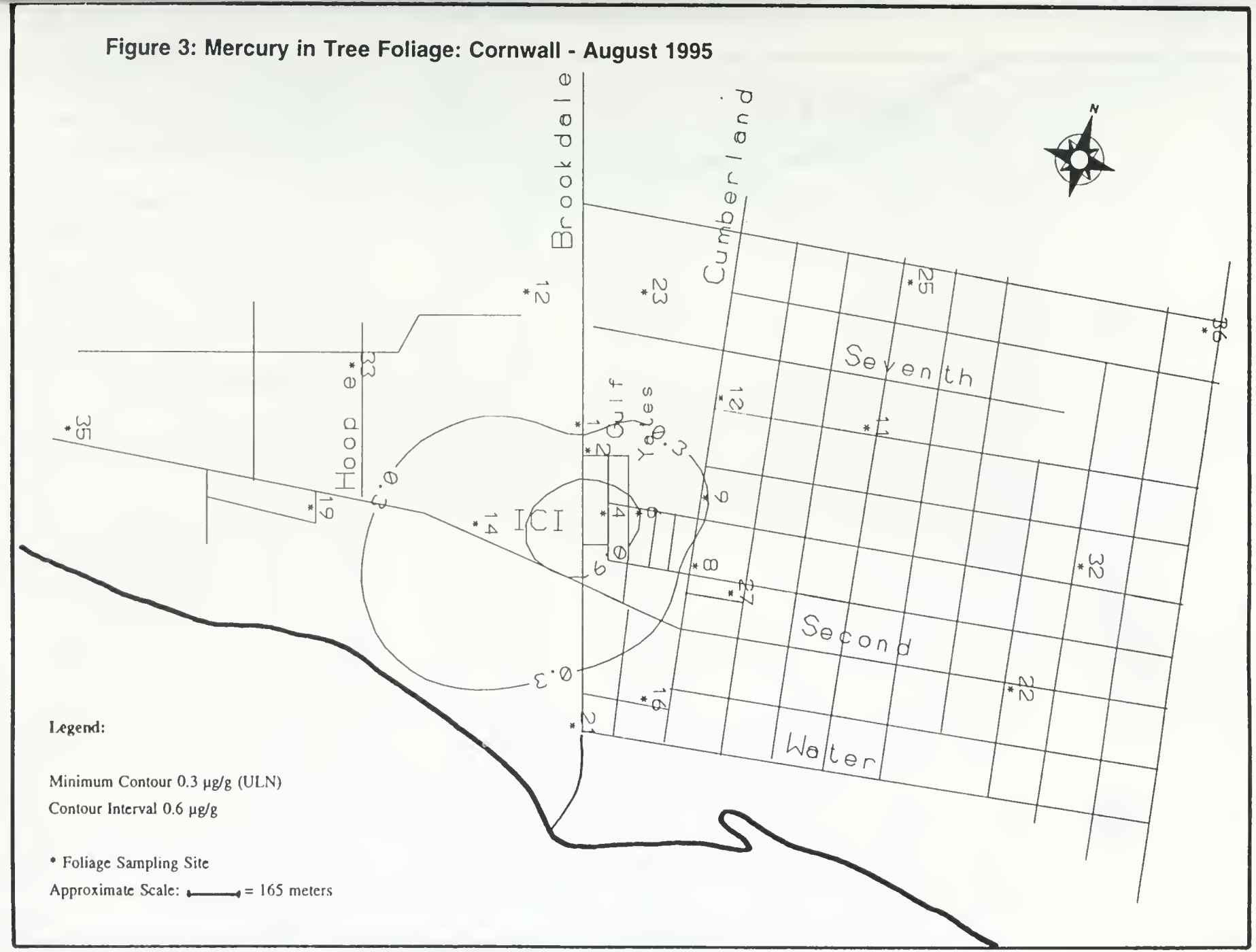

Figure 4: Mercury in Tree Foliage: Cornwall - August 1994

Legend:

Minimum Contour 0.3 µg/g (ULN)

Contour Interval 0.6 µg/g

* Foliage Sampling Site

Approximate Scale: ——— = 165 meters

Appendix A

Derivation and Significance of the MOEE Phytotoxicology "Upper Limits of Normal" Contaminant Guidelines.

The MOEE Upper Limits of Normal (ULN) contaminant guidelines represent the expected maximum concentration in surface soil, foliage (trees and shrubs), grass, moss bags, and snow from areas in Ontario not exposed to the influence of a pollution source. Urban ULN guidelines are based on samples collected from urban centres, whereas rural ULN guidelines were developed from non-urbanized areas. Samples were collected by Phytotoxicology staff using standard sampling procedures (reference: *Ontario Ministry of the Environment. 1989. Ontario Ministry of the Environment "Upper Limit of Normal" Contaminant Guidelines for Phytotoxicology Samples. Phytotoxicology Section, Air Resources Branch: Technical Support Sections NE and NW Regions, Report No. ARB-138-88-Phyto. ISBN: 0-7729-5143-8.*). Chemical analyses were conducted by the MOEE Laboratory Services Branch.

The ULN is the arithmetic mean plus three standard deviations of the suitable background data for each chemical element and parameter. This represents 99% of the sample population. This means that for every 100 samples that have not been exposed to a pollution source, 99 will fall within the ULN.

The ULNs do not represent maximum desirable or allowable limits. Rather, they are an indication that concentrations that exceed the ULN may be the result of contamination from a pollution source. Concentrations that exceed the ULNs are not necessarily toxic to plants, animals, or people. Concentrations that are below the ULNs are not known to be toxic.

ULNs are not available for all elements. This is because some elements have a very large range in the natural environment and the ULN, calculated as the mean plus three standard deviations, would be unrealistically high. Also, for some elements, insufficient background data is available to confidently calculate ULNs. The MOEE Phytotoxicology ULNs are constantly being reviewed as the background environmental data base is expanded. This will result in more ULNs being established and may amend existing ULNs.